

1)

5 nanometer Ta/1 nm Ru/2 nm NiFeCr/7 nm IrMn/2 nm CoFe/0.9 nm
Ru/2.5 nm CoFe/2 nm Cu/2 nm CoFe/2 nm Cu/5 nanometer Ta

(10-2)

This is to exemplify other embodiments of the bottom-type structure of Fig. 6, in which the free layer 122 is of a single-layered CoFe. The others are the same as in Example 3. The materials of the other layers except the free layer and the thicknesses of those other layers are the same as in Example 3. The merits of the single-layered free layer of CoFe are the same as in the top-type structure. In this Example, $M_s t$ is 3.6 nanometer Tesla in terms of NiFe. When this is compared with $M_s t$ of 4.5 nanometer Tesla, the thickness of the single CoFe free layer could be 2.5 nanometers and is thin. Even so thin, the single CoFe free layer could enjoy good spin filter effect. However, the two-layered free layer of NiFe/Co(Fe) shall have a large thickness to be 4 nm NiFe/0.5 nm Co, and it could not enjoy the spin filter effect for MR but shall be a simple shunt layer. In addition, NiFe itself also exhibits the shunt effect. Therefore, ΔR_s in the two-layered free layer is reduced by 0 to 30 %, based on that in the single-layered CoFe free layer.

As in the above, since the single-layered CoFe free layer in this Example could enjoy the MR spin filter effect in a broad range of $M_s t$, it is better than the laminated free

layer in Example 3.

In variations of (10-1) and (10-2), the high-conductivity layer may be of a laminate film composed of at least two layers, in place of the single-layer high-conductivity layer of Cu as disposed adjacent to the free layer of CoFe. For example, the laminate film for the high-conductivity layer may include Cu/Ru, Cu/Re, Cu/Rh, etc. The essential object of the two-layered high-conductivity layer is to control the magnetostriction λ_s in the free layer. This is because, as so mentioned hereinabove, the magnetostriction in the free layer of CoFe is influenced by the distortion of the free layer itself. Reduction in H_{in} is important in the invention. For reducing H_{in} , the two-layered high-conductivity layer will be effective. Embodiments of the variations are mentioned below.

5 nanometer Ta/2 nm NiFe/10 nm PtMn/2 nm CoFe/0.9 nm Ru/2.5 nm CoFe/2 nm Cu/2 nm CoFe/1.5 nm Cu/1.5 nm Ru/5 nanometer Ta
(10-3)

5 nanometer Ta/2 nm NiFe/7 nm IrMn/2 nm CoFe/0.9 nm Ru/2.5 nm CoFe/2 nm Cu/2 nm CoFe/1.5 nm Cu/1.5 nm Ru/5 nanometer Ta
(10-4)

In place of controlling the magnetostriction in CoFe by means of the laminated film for the nonmagnetic high-conductivity film as in the above, the magnetostriction in the free layer could also be controlled by varying the composition

of CoFe for the free layer. In general, it is easy to modify the subbing film for distortion control in the free layer. However, in bottom-type structures, it is often difficult to freely select the material for the subbing film for the free layer. In bottom-type structures, CoFe is laminated on Cu. In those, if $\text{Co}_{90}\text{Fe}_{10}$ (at.%) is employed, the magnetostriction of the free layer in the negative side will increase. In order to correct the magnetostriction to the positive side, Co-rich CoFe is desired. Concretely, desired are CoFe free layers of $\text{Co}_{90}\text{Fe}_{10}$ (at.%) to $\text{Co}_{96}\text{Fe}_4$ (at.%). However, the Co content of the free layer is too large, the Co-rich composition will have an hcp phase whereby the soft magnetic characteristics of the free layer will be lowered (that is, H_c in the free layer is increased). Therefore, too Co-rich CoFe alloys such as $\text{Co}_{98}\text{Fe}_2$ are unfavorable.

In those film structures, the specific resistance of Ru is $30 \mu\Omega\text{cm}$ while that of Cu is $10 \mu\Omega\text{cm}$. For the electrical shunt effect, Cu of 1 nanometer thick will be equivalent to Ru of 3 nanometer thick. In other words, in the films (10-3) and (10-4), the thickness of the high-conductivity film is equivalent to 2 nanometers in terms of Cu. For the single-layer Cu, its thickness may fall between 0.5 nanometers and 4 nanometers. Therefore, for Ru, its thickness may fall between 0.5 nanometers and 12 nanometers. However, Ru has a higher specific resistance than Cu and its spin filter effect